Automotive OTP NVM in TSMC Advanced Process Nodes

Kilopass Technology

ABSTRACT

Automotive has become a major consumer of semiconductors due to the increasing amounts of intelligence and connectivity being added to each new generation of cars. For semiconductor vendors this means ensuring every IP component incorporated into their designs meet the quality level—ISO/TS 16949, safety requirements—ISO 26262 ASIL (Automotive Safety Integrity Level), and product reliability standard—AEC-Q100 of car manufacturers. One component that is becoming ubiquitous in these designs is one-time-programmable (OTP) NVM to provide permanent storage for critical data contained in automotive System-on-Chips. This presentation will describe an antifuse OTP NVM being developed on the TSMC automotive IP platform that meets all the requirements for reliability and safety in the 16nm and soon the 10nm and 7nm process nodes where many new automotive designs are being fabbed.

Kilopass

Automotive OTP NVM in TSMC Advanced Process Nodes

Sept 13, 2017

Agenda

1. Kilopass Overview
2. OTP NVM for Automotive: Today and Tomorrow
3. Delivering TSMC IP9000A: Quality, Reliability, and **SAFETY**
4. Summary

  Kilopass

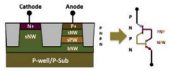
Kilopass Overview

Company

Since 2001
HQ in San Jose
10X Growth '08-'16

Leader in OTP (one-time programmable) Memory

70 + Patents
Integrated by 250 +
IDM or fabless companies
Over 10 billion units shipped



VLT (Vertical Layered Thyristor)

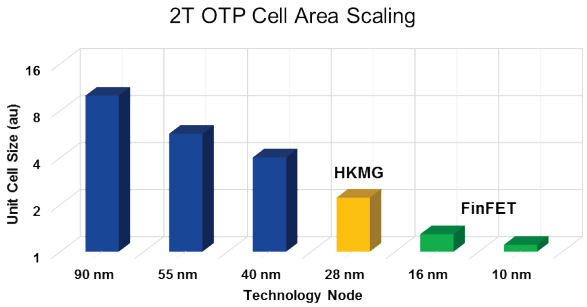
SRAM & DRAM
1/10 Standby Power
Silicon Proven Bit-Cell
Patents Issued and Pending

  Kilopass

OTP: Differentiation Through Cost-Flexibility Trade-offs

  Kilopass

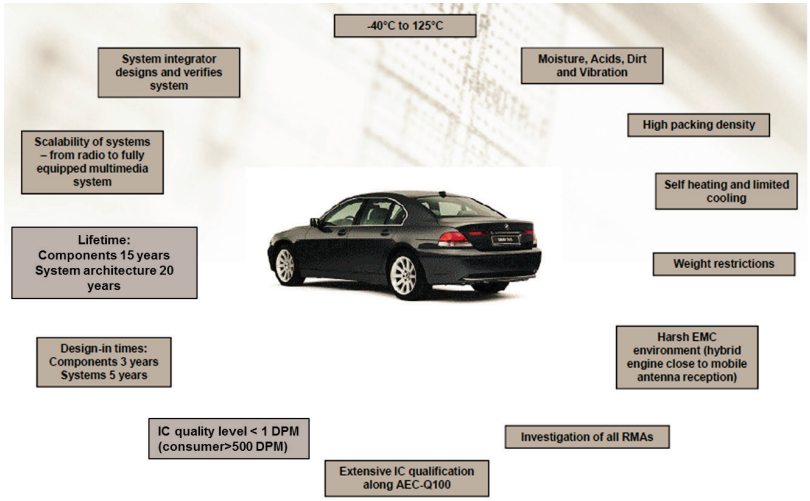
Scalability & Manufacturability



1. Standard NMOS – no special masks, overlay tolerance or process control
2. Follows standard Foundry DRC and DFM design rules
3. Scales with poly and active half pitches (P^2), thinner Gox requires lower programming voltage
4. Separate program and read transistors enables independent optimization of program, program disturb and parasitic leakages.

Kilopass

A Car, A Different Environment – Grade 1



Kilopass

Kilopass OTP Use Cases and Requirements in Automotive Grade-1

- Automotive chip developers need for OTP
  - Custom configuration string
  - Secure encryption key storage
  - Unique die serial number
  - Production test phase indicator
  - Trimming, calibration
  - Code storage to enable flexibility over ROM, ease of use over Flash for firmware
- Requirements for OTP
  - Field programmability
  - No additional mask layers
  - Program separate bits at different times
  - Automotive AEC-Q100 qualification, Grade 1
    - Programming and operating temperature range of -40C to 125C
    - Data retention: a 1k hour bake at 150C
    - Operation Life: Constant accelerated reads for 1k hours at 125C

Kilopass

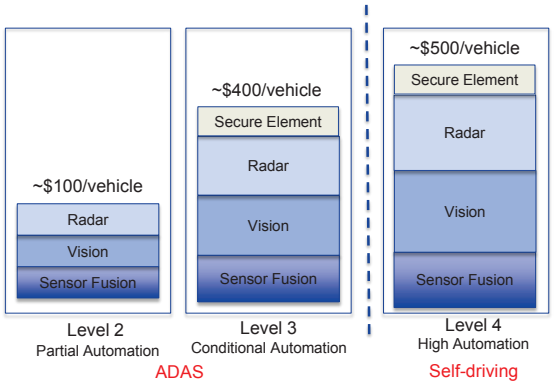
Kilopass Antifuse OTP in Cars Today at Grade 1

Kilopass

Reasons Automotive Customers Choose Kilopass

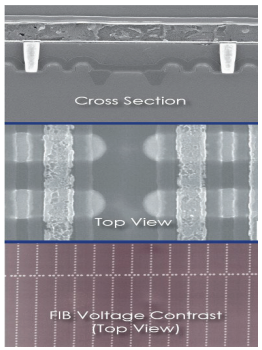
- Why Kilopass 2-T Antifuse Technology?
  - Not relying on trapped charges that could leak over time, not a floating gate technology
  - Cannot be erased by UV light
  - No known failure modes for programmed as well as unprogrammed bits
  - Standard CMOS; no additional processing steps
  - Qualification standard is the same as AEC-Q100, Grade 1
- Why Kilopass?
  - Technology scalability
  - Partnership with TSMC to delivery compelling solution
  - Offers assistance in automotive qualification effort at chip level

Delivering Self-Driving Car Next Big OTP Play



- Kilopass antifuse OTP essential values for self-driving automotive:
  - Scalability of Security
  - Scalability of Reliability
- Security foundational to connected cars
  - Privacy
  - Prevent unauthorized access
  - Increase safety
- OTP for secure code or key storage in SE and sensor fusion
- OTP for configuration and repair in radar and vision

Continue to Innovate in Security



Can you tell which bit is programmed?

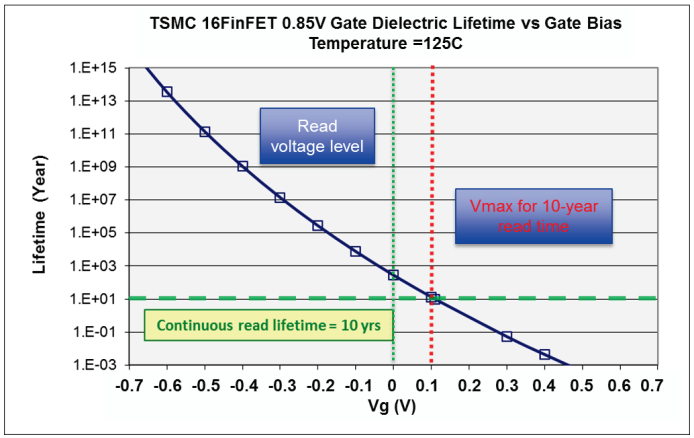
Kilopass Antifuse OTP protects against

Passive Attacks
- Glitching (F.G.)
- Power Analysis (F.G.)
- Data Permanence (F.G.)

Semi-Invasive Attacks
- UV Attacks (F.G.)
- Microscopy (e-fuse)
- Fault Injection (F.G.)
- Voltage Contrast (F.G.)
- Magnetic Scan (HDD)

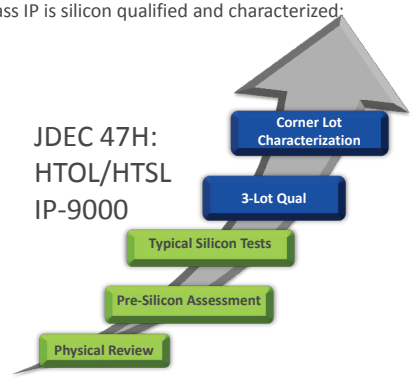
Invasive Attacks
- Chip Modification
- Micro-probing (e-fuse)
- Reverse-engineering
- Rear-side Approach (e-fuse)

Kilopass Antifuse Technology Scales to Delivery Reliability at 16nm FinFET



Kilopass OTP IP qualification & Delivery

- Kilopass IP is silicon qualified and characterized:



- IP is delivered as hard macro (gds) module:

Front-end Deliverables	Back-end Deliverables
Module Verilog Model (.v)	Module GDSII
Module Synopsys.lib (typ, bc, wc)	PIPO.LOG
Module Synopsys.db (typ, bc, wc)	Module Netlist (cdl)
Product Datasheet	DRC Summary
Testing Guideline	DRC Summary Readme
Integration Guideline	Shipment Readme
Prelim Module LEF	LVS Report
	Final Module LEF
	Module Antenna LEF
	Antenna Report
	Version File

Kilopass

Kilopass OTP IP Testing Methodology Guideline

- With DFT properly implemented, Kilopass' OTP products can be readily tested from the SoC top level. A combination of the following methods is recommended:
  - Direct IP Access,
  - MUX'ed Isolation,
  - Scan Chain.
- Kilopass' OTP can be programmed at wafer sort, final test or in-system/in-field. Depending on where the programming occurs, end user can implement and use some of or all the available test modes.

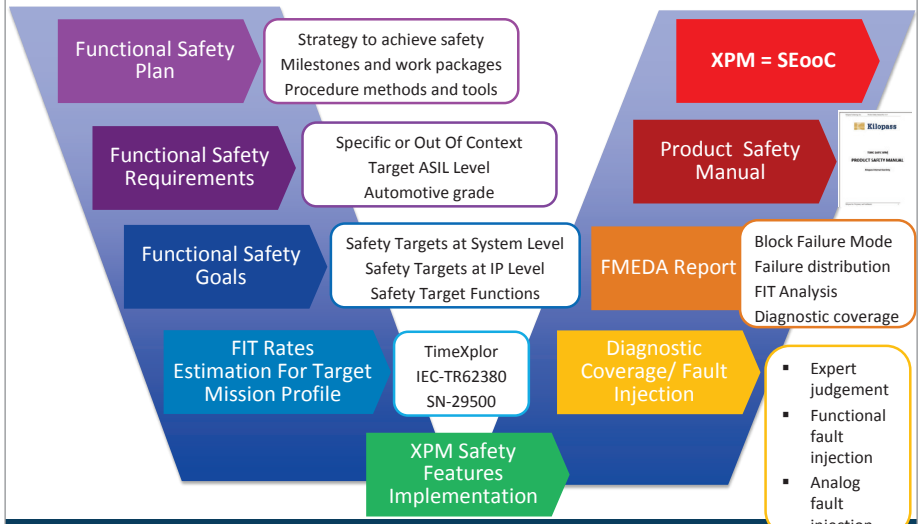
Test Mode	Description	Failure Criteria
Blank Check	Stress read at elevated internal read voltage.	Fail, if any bit isn't data "0".
TESTDEC	Test for WL & BL Integrity.	Fail, if any bit isn't matching expected TESTDEC pattern.
WRTEST	Test programmability before actual program on spare rows.	Fail, if any bit isn't matching expected pattern.
Program & Verify	Program Verify Mode w/ lower regulated read voltage.	Fail, if any bit isn't the expected value.

Kilopass

Kilopass Automotive OTP Product Development

Kilopass

Implementation of the ISO26262 Functional Safety Flow



Kilopass

Failure Modes Effects and Diagnostic Analysis

Single Point Fault Violating a Safety Goal

Diagnostic Mechanism to Catch Fault

Fault Diagnostic Coverage

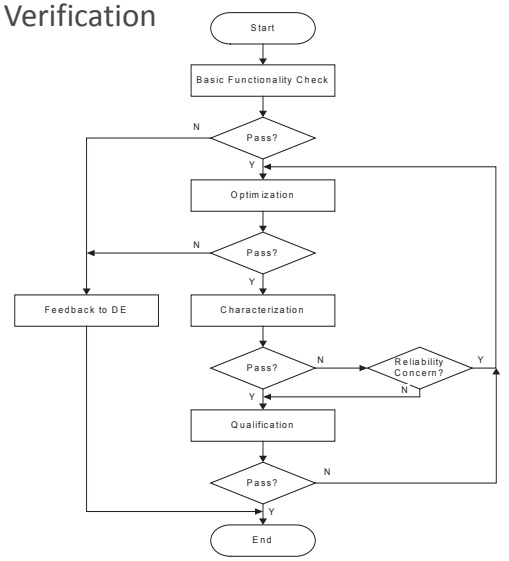
Multiple Point Fault Violating a Safety Goal

No	Block/Sub-block name	Block type	Permanent Failure Rate (λ, [FIT])	Failure Mode (FM) for the Block	Effect description of the Failure Mode	Failure rate distribution	Y	Diagnosis to be considered				ASIL Estimation (ASIL D)		
												SPFM(Internal)=	MPFM(Internal)=	LFM
												99.94%	99.96%	99.93%
							SGV1	Diagnosis ID	DC Value estimated (for single point failures)	DC value estimated (for multiple point failures)	DC value estimated (for transient failures)	Safe fault internal [FIT]	SPF/RF[FIT] =λ.single(1-DC)	MPF[FIT]= LMPF(1-DC)	LFM
1	Controller	Logic		driver break-down	incorrect program/read data	100%	S	D001	99.9%						
2	HV generator	Power		high-voltage breakdown	VPP low unable to program	50%	S	D001	99.9%						
				low current capability	VPP low unable to program	50%	M	D001	0.0%	99.9%				3.52E-04	
3	Memory array	OTP array		single-bit failure	incorrect program/read data	100%	S	D001	99.9%						
4	Sense amplifier	Sensing		bit-line leakage	incorrect program/read data	100%	S	D001	99.9%						
5	Address decoder	Logic		driver break-down	incorrect program/read data	100%	S	D001	99.9%						
6	Ouput Selector	Logic		driver break-down	incorrect program/read data	100%	S	D001	99.9%						
	Total:														

Kilopass

Kilopass OTP Test Chip Verification

- Test chip testing procedures:
  - Function Evaluation
  - Setting Optimization
  - Device Characterization
  - Qualification



Kilopass

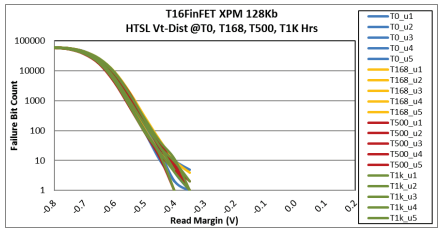
Reliability: AEC Q100 Qualification

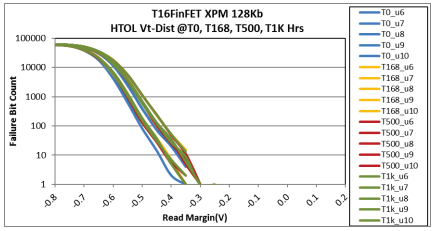
Test Description	Stress Condition	Sample Size Acceptance #/Lot	Qualification Requirement	Test Condition after Stress
High Temperature Operating Life (HTOL)	Ta=150 °C for 1000 hrs Vdd=Nom +40% & Vddio= Nom +30% Device programmed with checkerboard pattern	100 modules/lot 0 failures	3 lots 1 device per Kilopass family	Std. Kilopass QA test program @RT, CT, HT (in that order)
High Temperature Storage Life (HTSL)	Ta=175 °C for 1000 hrs, unbiased bake, Device programmed with checkerboard pattern	100 modules/lot 0 failures	3 lots 1 device per Kilopass family	Std. Kilopass QA test program @RT, HT (in that order)
ESD: HBM	JEDEC STD JESD22-A114-E (HBM) Device programmed with checkerboard pattern	9 parts/lot 0/18 failures +/-2000V HBM	3 lots 1 device per Kilopass family	Std. subcontractor ESD test and Std. Kilopass QA test program
ESD: MM	JEDEC STD JESD22-B115-A (MM) Device programmed with checkerboard pattern	9 parts/lot 0/18 failures +/-100V MM	3 lots 1 device per Kilopass family	Std. subcontractor ESD test and Std. Kilopass QA test program
Latch-Up	JEDEC STD JESD78A Device programmed with checkerboard pattern	3 parts/lot 0/3 failures +/-100mA	3 lots 1 device per Kilopass family	Std. subcontractor Latch-Up test and Std. Kilopass QA test program

Kilopass

Reliability: Read Margin before and after Stress

- More than 300mV read margin remain after 1000hr HTOL/HTSL





Kilopass

Quality Management using Unified Milestone System

- Kilopass uses the Unified Milestone System (UMS) as a process for tracking the product life cycle under the quality management system.
  - UMS describes all the major milestones and review points within the development process
  - UMS identifies the required checklists and standards for completing each milestone, allowing for tracking and control for the design and development stages through qualification
  - UMS aligns all functional organizations to improve our execution throughout the life cycle
  - UMS provides a consistent methodology and definition to ensure that every product goes through the same quality checks for error prevention
  - Example of the Milestones for UMS:

Quality Management: TS16949 Compliance

- UMS along with the QMS checks off requirements for TS16949:2009

ISO9001 TS16949 Clause	Title	QMS/UMS coverage
4.1.	Quality Management System General requirements	QMS
4.2.3.1.	Engineering specification	UMS
5	Management responsibility	QMS
6	Resource management	QMS
7	Product realization	UMS
7.1.	Planning of process and product realization	UMS
7.1.3.	Confidentiality	QMS
7.1.4.	Change control	QMS
7.2.	Customer-related process	UMS
7.2.1.	Determination of requirements related to product	UMS
7.2.2.	Review of requirements related to the product	UMS
7.2.3.	Customer communication	UMS
7.3.	Design and development	UMS
7.3.6.3.	Product approval process	UMS
8.5.1	Continual Improvement	QMS

Summary

- Kilopass antifuse OTP is manufactured in standard CMOS logic processes, and is scalable from 180nm to 10nm and below process nodes.
- Antifuse OTP is an idea choice for secure and reliable eNVM in automotive systems.
- Kilopass antifuse XPM™ OTP NVM implemented in T16FinFET technology is designed in ADAS IC.
- Kilopass follows TSMC9000A guidelines on automotive OTP IP development.
  - Kilopass uses UMS for quality management in product development.
  - Kilopass delivers safety documents compliant with ISO26262 with IP shipment.
  - Kilopass automotive IP test chip go through AEC-Q100 qualification.

Thank You!